§9. Discovery of Electric Pulsation

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Amongst fusion oriented devices, toroidal helical devices (e.g., stellarator, torsatron, heliotron) are supposed to realize a `static plasma . This is because static external coils alone can produce the necessary magnetic field for confinement, without internal plasma current sometimes leading to violent instabilities such as sawtooth oscillations and disruptions.

Nonlinear nature of toroidal helical plasmas can give birth to violent behavior associated with bifurcation. We have discovered, in fact, in a toroidal helical plasma, however, a `dynamic steady state' with a self-excited oscillation in its electrostatic potential profile. This phenomenon, denoted as `electric pulsation', indicates the toroidal helical plasma can self-organize dynamic steady states under a constant and static external condition.

Figure 1 shows the electric pulsation observed in the potential at the plasma center, together with time evolution of the line-averaged electron density. The combined ECH+NBI heating continues from t=44ms to t=96ms in this case. In the steady state(55 <t < 95ms), negative bursts of potential by -0.6kV occur quasi-periodically in every 2ms. The pulsations appear to repeat swinging between two states of higher and lower potential of $\phi(0)$= 0.8kV and 0.2kV. The plasma stays longer in the higher potential state. The potential collapses and recovers in typical timescales of 30μs and 140μs, respectively. These timescales (~microseconds) are much faster than the diffusive one (~milliseconds). This fast timescale manifests the transitory nature of the phenomenon

Potentials at other locations also exhibit quasi-periodic bursts with similar interval but different amplitude and polarity. In contrast to the bursts near the plasma center, positive bursts are observed in outer plasma radius. The pivot point at which the burst changes its polarity is located around the normalized plasma radius ρ=0.53, as is shown in Fig. 2.

In Fig. 2, the averages of local maximums and minimums in the periods including a burst are plotted, hence, the fitting curves represent two states before and after the crashes. The plotted data were sequentially taken shot by shot with an identical operational condition. Around the center, the derivative of potential (the electric field) does not change so much before and after the crashes. A large change of the electric field, as a result, occurs around the pivot during a crash.

In summary, the phenomenon clearly demonstrates that the bifurcation property of radial electric field can make the toroidal helical plasma very dynamic even in low beta regime.

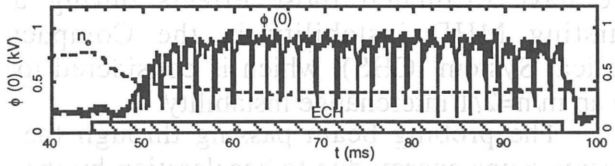

Fig. 1. Electric pulation occurs in a combined ECH+NBI heating phase.

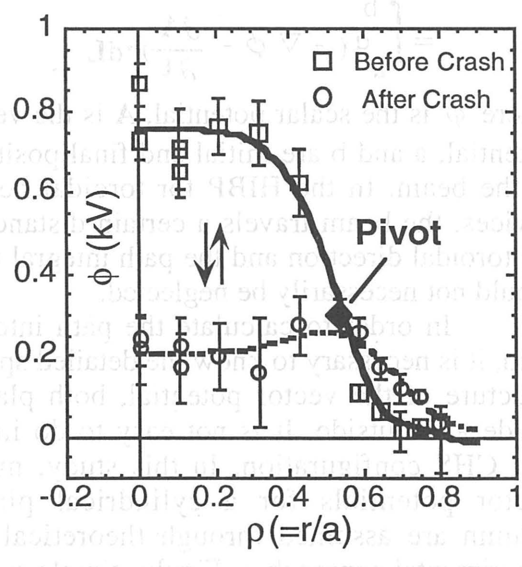

Fig. 2. Two states that the plasma takes during electric pulsation.

References
1) A. Fujisawa et al., Phys. Rev. Lett. 79, 1054(1997).